

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

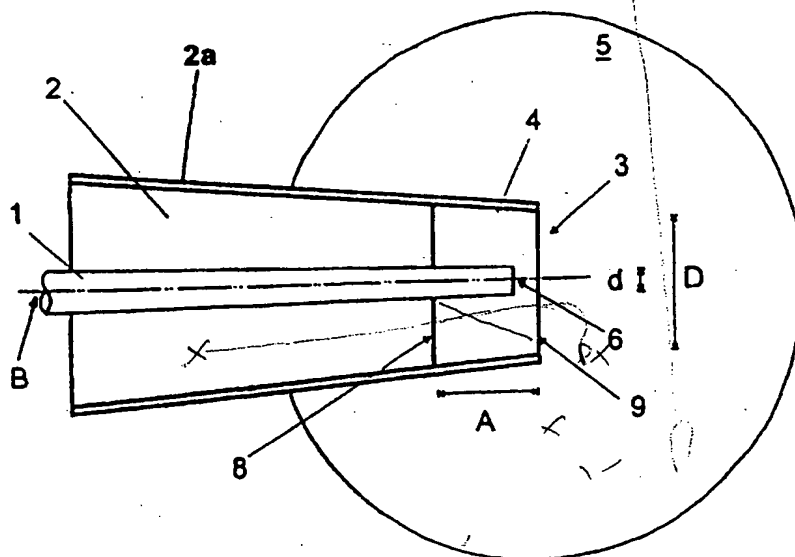
**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problems Mailbox.**

**THIS PAGE BLANK (USPTO)**

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup>:</b>  <b>G01F 1/64</b>	<b>A2</b>	<b>(11) International Publication Number:</b> <b>WO 97/46853</b>  <b>(43) International Publication Date:</b> 11 December 1997 (11.12.97)
<b>(21) International Application Number:</b> PCT/DK97/00250 <b>(22) International Filing Date:</b> 4 June 1997 (04.06.97)  <b>(30) Priority Data:</b> 0633/96                      6 June 1996 (06.06.96)                      DK  <b>(71) Applicant (for all designated States except US):</b> UNISENSE [DK/DK]; Forskerparken, Gustav Wieds Vej 10, DK-8000 Århus C (DK).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> REVSBECH, Niels, Peter [DK/DK]; Thorshavnsgrade 3, DK-8200 Århus N (DK). NIELSEN, Lars, Peter [DK/DK]; Mårslet Elle, Bedervej 83, DK-8320 Mårslet (DK). PEDERSEN, Ole [DK/DK]; Ørslevgade 76E, DK-4100 Ringsted (DK). GUNDERSEN, Jens, Kristian [DK/DK]; Søskrænten 19, DK-8260 Viby J. (DK).  <b>(74) Agent:</b> DANFOSS A/S; Patent Dept., DK-6430 Nordborg (DK).		<b>(81) Designated States:</b> AM, AT, AU, BA, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KR, KZ, LT, LU, LV, MD, MK, MX, NO, NZ, PL, PT, RO, RU, SE, SG, SI, SK, TR, UA, US, UZ, VN, YU, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>

**(54) Title:** METHOD FOR MEASUREMENT OF FLOW VELOCITY OR DIFFUSIVITY, MICROSENSOR AND APPLICATION OF SUCH MICROSENSOR

**(57) Abstract**

The invention relates to a method and a microsensor for measurement of transport coefficients like diffusivity or flow velocity. The microsensor has a reservoir (2) provided with a mouth (3) and a transducer (1). The reservoir contains one or more gasses or one or more liquid-dissolved substances intended for the diffusion through the mouth into an area or field (5) of a medium outside the mouth of the reservoir. The transducer measures the partial pressure of the gas or the concentration of the liquid-dissolved substance in the mouth, whereby transport coefficients of diffusivity or flow velocity are determined. Preferably, the gradient of the partial pressure or the concentration is determined.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

**Method for measurement of flow velocity or diffusivity,  
microsensor and application of such microsensor**

5 The invention relates to a method for the measurement of  
diffusivity or flow velocity. The invention also relates  
to a microsensor for measurement of diffusivity or flow  
velocity, which microsensor has a reservoir provided  
with a passage- or transport area and at least one  
10 transducer.

Several principles are known for the measurement of flow  
velocity in fluids. For example the induction principle  
(Faraday-principle), the skin friction/hot wire princip-  
15 le and the Laser-Doppler-principle. All these principles  
make use of measuring devices with considerable dimensi-  
ons. Consequently, the medium where the measurement  
takes place have to fulfill specific requirements such  
as sufficient flow and volumen.

20 The US 5,339,694 describes a sensor for measurement  
of flow in a matrix, more precisely measuring migration  
of groundwater. The sensor consists of a circular pipe  
having a liquid permeable diaphragm. Outside the cylin-  
25 der are transducers for measurement of conductivity. The  
cylinder contains a saline solution with a conductivity  
that differs from that of groundwater. When the sensor  
is placed in a water saturated stratum, salt ions from  
the cylinder will diffuse through the permeable  
30 diaphragm into the stratum with groundwater. A change in  
the conductivity in an area outside the cylinder is re-  
gistered by the sensors outside the cylinder, whereby  
the flow velocity can be determined.

35 This sensor makes use of a suitable principle for the  
determination of small flow velocities through bigger  
volumes of a matrix. However, due to the dimensions of  
the sensor, it is not possible to use it in smaller vo-

CONFIRMATION COPY

lumes such as layer transistions in fluids or in vessels in vegetable or animal tissues, in filters or biofilm.

Thus, the aim of the present invention is to provide a  
5 method and a sensor, which makes use of a better spatial resolution and provides a lower limit of measurement than described in prior art, and which can measure transport coefficients like diffusivity or flow velocity in fluids such as liquids or gasses, or measure in  
10 porous matrixes or close to surfaces.

In particular, it is an aim to provide a sensor which can measure in systems where transport of substance or matter takes place as a combination of diffusivity and  
15 advection as e.g. close to surfaces and in porous matrixes.

This is achieved with a method as described in claim 1 where the sensor is placed in an area or volumen of a  
20 medium, that a gas or a dissolved substance is diffused into this medium hereby functioning as a tracer material, that the diffusivity or the flow velocity is determined by measuring either the partial pressure of the gas or a concentration of the gas or liquid dissolved  
25 substance, whereby the measurement is carried out in the passage- or transport area on the gas or liquid dissolved substance.

According to the invention - as described in claim 6 -  
30 a first microsensor is characterized in that the transducer has a sensoric tip, that is placed in the passage- or transport area, and that the sensoric tip of the transducer is placed in the mouth of the passage- or transport area.

35

As described in claim 7 and 8, a second embodiment of a microsensor according to the invention is characterized in that the transducer or measuring device is surrounded

by the reservoir, which contains a gas or liquid dissolved substance. Preferably, the passage- or transport area is equipped with a permeable membrane or insert, open for diffusion, which is placed in and in sealing contact to the mouth, that the transducer tip is placed in the membrane or insert, and that the reservoir contains a gas or a liquid-dissolved substance intended for diffusion from the reservoir through the membrane or insert to an area or volumen outside the mouth.

10

The transducer can either be placed longitudinally, as depicted in claim 9, with its axis parallel with the axis of the passage- or transport area and with the sensoric tip placed in the membrane, or with its axis and sensoric tip mainly vertical to the axis of the passage- or transport area as stated in claim 10. Especially the longitudinal solution allows a space saving sensor design.

20 Microsensors with these features can be minituarized to such a degree that diffusion coefficients as well as very low flow velocities can be measured.

Measurement by means of the inventive microsensor is a true in-situ measurement, and the placing of the microsensor in the medium will not cause substantial changes in transport coefficients. The use of the microsensor does not require a given minimum diffusion coefficient or flow velocity.

30 The term "fluid" is to be broadly understood as liquids or gasses, and also incorporates gasses with a mist of liquid in the gas or a liquid with a gas contained in the liquid.

35 The transducer is mainly an electrochemical microsensor, for example a Clark type oxygen micro-electrode, but other types of microsensors like sensors based on optical fibres, so-called optrodes can be used too.

The membrane or insert described in the second embodiment of a microsensor according to the invention is placed at the mouth of a container and is preferably made of silicone.

However, materials that are diffusible or permeable for dissolved non-ionized substances can also be used. The measuring principle for the microsensor can hereby be extended in a way that it comprises not only diffusion of gasses but also diffusion of liquid-dissolved substances like dissolved non-ionized substances from a liquid in the reservoir. The microsensor according to the invention can perform measurements in both gas and liquid media.

The sensor may have a circular mouth at the end of the container, the mouth having a diameter of between 2  $\mu\text{m}$  and 3 mm, preferably between 2  $\mu\text{m}$  and 100  $\mu\text{m}$ . For the measurement of flow velocity 20  $\mu\text{m}$  is preferred whereas 100  $\mu\text{m}$  is ideal for measurement of diffusion coefficients. The axial length of the membrane or insert is between 2  $\mu\text{m}$  and 10  $\mu\text{m}$ , preferably 20  $\mu\text{m}$  for measurement of the flow velocity and 100  $\mu\text{m}$  for measurement of diffusion coefficients.

Using this microsensor it is possible to reach a lower limit for measurement of flow velocity which is less than 5  $\mu\text{m/s}$  - that is a factor 100 lower than known from prior art. These low values can be measured by the microsensor, where measurement of a partial pressure or a concentration takes place over a very small length inside the sensor. Due to the small dimensions the volume of the medium where the measurement takes place may be reduced considerably.



The sensor is among other uses intended for measurement of flow velocities in fluids with little flow, or in gasses and liquids close to surfaces, but can advantageously be used in other areas, like in human vessels.

5 Furthermore, the microsensor is intended for measurement of transport conditions in the form of combined diffusion and flow in porous matrixes in for example biofilm in bioreactors or in animal tissues like brain or liver. Also, measurement in sediments of the sea bed is possible. Hitherto, measurement has mainly been done through  
10 use of tracer elements fed into the medium with measurements carried out in the medium itself. With the present invention it is now possible to measure in-situ the transport of miscellaneous substances in vessels, as for  
15 example in human tissues.

Consequently, the sensor can be used in many different applications within medical and scientific research as well as within industrial branches like medical and biotechnological industry, where the exchange of a substance between solid surfaces and liquids is an interesting  
20 parameter.

Below is a detailed description of the invention  
25 according to the enclosed drawings, where

figure 1 is a cut-away of a first embodiment of a microsensor according to the invention,

30 figure 2 is a cut-away of a second embodiment of a microsensor according to the invention

figure 3 is a schematic illustration of a measurement of low and high flow velocity

35

figure 4 is an illustration of an embodiment of a mouth in a microsensor according to the invention

figure 5 is a graphical illustration of a calibration process for the microsensor according to the invention, and

- 5 figure 6 is a graphical illustration of an estimated measuring range with the microsensor according to the invention.

Figure 1 describes a first embodiment of a microsensor according to the invention. The microsensor has a transducer 17 for example an oxygen microelectrode or a fibre optical sensor. Alternatively, a hydrogen electrode or a nitrous oxide electrode can be used. A reservoir 2 has a passage- or transport area connecting the reservoir and the medium, the passage- or transport area designed as a mouth 3. The transducer 1 has a sensoric tip 6 in the mouth 3, and the transducer 1 is placed perpendicular to the longitudinal axis B of the passage or transport area.

20

The transducer 1 is placed in an enclosure 10 that surrounds the transducer and the reservoir. The enclosure 10 is inserted in a wall 11 which could be the side wall of a tank or a pipeline containing the medium where the measurement is to take place. The enclosure 10 may be produced of different materials, for example glass or metal or other diffusion-proof material. The reservoir 2 contains a gas or liquid-dissolved substance intended for the diffusion through the mouth 3 into an area 5 outside the mouth 3.

30

As described, the transducer 1 has a sensoric tip 6 where a partial pressure of the gas in the mouth 3 or a concentration of the dissolved substance in the mouth 3 is being measured.

35

In the shown embodiment the diameter  $d$  of the tip 6 is 2  $\mu\text{m}$ , and a diameter  $D$  of the mouth 3 is 10  $\mu\text{m}$ .

The area 5 outside the mouth 3 of reservoir 2, into which the gas or the liquid-dissolved substance contained in the reservoir 2 is to diffuse, will in stagnated media be spherical as illustrated. The geometry of the area 5, however, depends on the kind of medium and on the diffusivity and flow conditions in the medium, into which the gas or the dissolved substance diffuses.

- 10 The reservoir 2 could contain a liquid with dissolved non-ionized combinations or a gas. Gas contained in the reservoir 2 is mainly hydrogen ( $H_2$ ), carbon monoxide (CO), oxygen ( $O_2$ ) or nitrous oxide ( $N_2O$ ). Applied as tracer, hydrogen ( $H_2$ ) is the preferred gas, because it
- 15 only appears in modest quantities in the media which flow has to be determined. Oxygen on the contrary, is frequently present in the media and can interfere with the measurements of the transducer.
- 20 Figure 2 illustrates a second embodiment of a front part of a microsensor according to the invention. The microsensor comprises a transducer 1, for example an oxygen microelectrode or a fibre optical sensor. Alternatively a hydrogen electrode, a carbon monoxide electrode or a
- 25 nitrous oxide electrode can be used. A reservoir confined by a container 2a has a mouth 3. In the mouth a permeable membrane or insert 4 is placed. The transducer 1 has a tip 6 inserted in the mouth 3, and the transducer is placed with its longitudinal axis parallel with the
- 30 longitudinal axis B through the microsensor.

The reservoir 2 enclosed by the container 2a surrounds the transducer 1. The permeable membrane or insert 4 in the mouth 3 is in sealing contact with the container 2a.

35 The container is made of a material that is not permeable for gasses, for example a metallic material or glass. The membrane or insert 4 is made of silicone. The reservoir 2 contains a gas or a dissolved substance in-

tended for diffusion out through the membrane or insert 4 to an area 5 outside the mouth 3 of the container 2a.

As mentioned, in a stagnant medium there will be a spherical diffusion field around the outside of the mouth 3, with decreasing concentrations with increasing distance to the orifice. Spherical diffusion comes to a steady state, and after a short time the concentration field around the mouth of the microsensor will not change, i.e. the transducer 1 placed in the membrane or insert 4 reads a constant concentration. If a flow is imposed in the media 5, the diffusion field will be disturbed as advection will now contribute to the transport of molecules away from the mouth, i.e. the concentration in and outside the membrane 4 will decrease. The higher the flow, the lower the concentration will be in the membrane, where it is sensed by the built-in transducer. The average diffusion time of a gas molecule through a 20 $\mu$ m thick membrane is about 0.05 s, so the response to changes in flow rate has about the same time constant with a 90% response below 1 s. The response time will increase with the diameter of the sensor and will be largest at low flows, where the diffusion sphere around the sensor is wide.

As described the transducer 1 has a sensoric tip 6 where the partial pressure or pressure gradient of the gas in the mouth 3 or alternatively the concentration or its gradient of the dissolved substance in the mouth 3 is being measured. Preferably, the measurement of partial pressure or concentration is carried out on tracer material, which has not yet been led into the external medium. As seen on Fig.2, the transducer 6 measures at the end of the mouth 3, just before the tracer enters the outer field 5. From prior art it is known to add a tracer to a flowing medium, and to place the measuring device or transducer directly in the flowing media, exposed to mechanical inflation, surface growth and possi-

ble interference on the output signal by outside elements. Instead, measuring inside the passage and placing the transducer in an insert gives a controlled and well defined measuring environment. The insert 4 defines a  
5 confined chamber or volumen (8,9,A,D) which influences upon the diffusivity of the tracer. The silicone insert impedes the diffusivity, and results in linear curves representing the partial pressure or the concentration. In the shown embodiment an axial length A of the membra-  
10 ne or insert 4 is 10  $\mu\text{m}$ . A diameter d of the tip 6 of the transducer is 2  $\mu\text{m}$ , and a diameter D of the mouth 3 is 10  $\mu\text{m}$ . By enlarging the distance A thereby lengthening the insert, a comparatively larger part of the curve profile is inside the microsensor, which is relevant  
15 when measuring small changes in diffusivity. To enhance the sensitivity of measurement, the transducer 1 can be placed outside the membrane or insert 4. However, this means loss of the linear pressure or concentration profile. Also, the insert can be moved and e.g. be placed  
20 in the middle of the container 2a between reservoir and mouth 3.

The area 5 outside the mouth 3 of container 2a, into which the gas or the liquid-dissolved substance contained in the reservoir 2 is to diffuse, is in stagnated  
25 media spherical as mentioned. The geometry of the area 5, however, depends on the kind of medium or the diffusivity and flow conditions in the medium, into which the gas or the dissolved substance diffuses.

30

Gas contained in the container 2a is mainly hydrogen ( $\text{H}_2$ ), carbon monooxide ( $\text{CO}$ ), oxygen ( $\text{O}_2$ ) or nitrous oxide ( $\text{N}_2\text{O}$ ). The reservoir 2 can also contain a liquid with dissolved non-ionized combinations.

35

Figure 3 illustrates curves for a partial pressure of the gas or the concentration of the liquid-dissolved substance contained in the reservoir 2, which diffuses through the membrane or insert 4 into the area 5 of the medium outside the mouth 3. The partial pressure or the concentration is illustrated as a function of the position in the microsensor as illustrated by the longitudinal axis B. The first curve L illustrates the partial pressure or the concentration at diffusion out into a medium with a low flow velocity. The second curve H illustrates the partial pressure or the concentration at diffusion out into a medium with a higher flow velocity. It appears that the partial pressure of the gas or the concentration of the dissolved substance is being reduced as soon as the gas or the dissolved substance begins to diffuse through the membrane or insert 4 from the back 8 to the front 9 of the membrane or insert 4. In other words, the diffusivity or flow velocity is imaged by the concentration or pressure curves. In particular, by measuring in only one point on the curve as shown with the transducer 1, the gradient of the curve can be determined either by means of a look up table or by a simple calculation based on the knowledge of the start pressure or concentration in the reservoir.

25

In a medium with high flow velocity the partial pressure or concentration will decrease with a numerically large constant gradient from the back 8 of the membrane or insert 4 on to the front 9. From the front 9 the partial pressure or the concentration will decrease with a continuous non-constant gradient. In the start the gradient is numerically larger than the gradient in the membrane or insert 4 but will decrease until a distance b is reached, where the gradient is almost zero.

35

In a medium with low flow velocity the partial pressure or the concentration decreases with a numerically small constant gradient from the back 8 to the front 9. From

the front 9 the partial pressure or concentration decreases with a continuously non-constant gradient. In the beginning, the gradient is numerically larger than the gradient in membrane, but decreases until a distance b  
5 is reached, where the gradient is almost zero.

Figure 4 illustrates an embodiment of the mouth 3 in a reservoir 2 and a container 2a. The mouth is shown from a front 12 and has preferably a circular sectional view.  
10 In the figure, only the tip 6 of three transducers 1 is shown. Using three or more flow sensors allows a spatial measurement, which can determine the direction of flow. One of the transducers (1) with mouth 6 could be a flow sensor as described herein, which releases a tracer  
15 to be detected by the other transducers for determining the flow direction. Different geometries of placing the transducer tips are possible; for example, a flow sensor according to the invention could be placed in the center and surrounded circularly by a number of n tracer trans-  
20 ducers, where the number n determines the resolution of the measurement.

Diffusivity and flow velocity can be measured by means of different types of transducers and with mixed gasses  
25 or liquid dissolved substances contained in the reservoir 2. For example, a first transducer can be used for the measurement of diffusivity and a second transducer for the measurement of flow velocity, with both transducers placed in the mouth 3.

30

Furthermore, a set of different types of transducers can be inserted in the mouth 3 for the measurement of diffusivity or flow velocity and also measurement of temperature with a thermosensor. Alternatively, instead of the  
35 mouth 3 having a circular sectional view, a mouth with slots can be provided, as known from the art for measurement of shear stress.

Figure 5 is a curve illustrating the calibration of a microsensor according to the invention. The calibration is done for a flow velocity of between 0  $\mu\text{m/s}$  and 100  $\mu\text{m/s}$ . It appears that the sensor output generally decreases linearly in proportion to the flow velocity. The mathematical function followed by the calibration curve is shown above the curve.

Figure 6 illustrates a calculated velocity-current curve of a speed range from 0  $\text{mm/s}$  to more than 10  $\text{mm/s}$ . The curve is calculated on the basis of the formula shown above the curve. The output of the microsensor decreases exponentially with the flow velocity, but exhibits a close to linear profile at low velocities below 2,5  $\text{mm/s}$ .

This invention is described according to specific embodiments. It will, however, be possible to carry out the invention with other design relations between the transducer, the reservoir and possibly the membrane or insert. The embodiment shown in figure 1 as well as the one shown in figure 2 are available with or without membrane or insert. Other kinds of material than those mentioned can be used for the production of microsensors, the transducer for example can be a fibre optical sensor. More than one transducer or several types of transducers can be used as the measuring device, as well as gas or liquid-dissolved substances or compounds as tracer material. To compensate for temperature differences or temperature gradients the microsensor can also be equipped with a thermo-transducer.



Patent Claims

1. Method for the measurement of transport coefficients  
5 as diffusivity or flow velocity in a medium like a gas,  
a liquid or a matrix, where a measuring device measures  
a tracer which in gaseous, liquid or liquid dissolved  
form is led from a reservoir into the medium characteri-  
10 zed in that the concentration or the partial pressure of  
the tracer is measured in a passage- or transport area  
(3), which connects the reservoir (2) and the medium,  
and preferredly has the form of a channel or a mouth,  
whereby the measurement is carried out on tracer materi-  
al in the passage- or transport area.

15  
2. Method according to claim 1 characterized in, that  
the measuring device determines a curve profile, espe-  
cially the gradient of the curve, the curve relating to  
the partial pressure or the concentraion of the tracer  
20 in the passage- or transport area.

3. Method according to claim 2 characterized in that the  
measuring device measures the partial pressure or the  
concentration at only one point in the passage- or  
25 transport area and that the measured value is converted  
to a gradient of the partial pressure or the concentra-  
tion.

4. Method according to claim 3 characterized in that the  
30 partial pressure or the concentration measured in only  
one point is compared to known data in an existing data-  
base, which gives information of a relationship between  
the in only one point measured partial pressure or con-  
centration and the gradient of the partial pressure or  
35 the concentration.

5. Method according to one of the above claims characte-  
rized in that the passage- or transport area contains a

device (4), which influences upon the diffusivity of the tracer, said device defining a confinement or volumen (8,9,A,D, Fig.2) in which the concentration or the partial pressure of the tracer is measured by the measuring  
5 device.

6. Microsensor for measuring transport coefficients like diffusivity or flow velocity in a medium like a gas, a liquid or a matrix, said microsensor incorporating a measuring device and a reservoir containing a gas or a  
10 substance dissolved in a liquid characterized in that the measuring device (1) has a sensoric tip (6) which is placed in a passage- or transport area (3), which connects the reservoir (2) and the medium, and  
15 preferably is made as a channel, and where the sensoric tip is placed close to the mouth of the channel.

7. Microsensor according to claim 6 characterized in that the reservoir (2) surrounds the transducer or measuring device (1), said reservoir containing a gas or a  
20 liquid dissolved substance intended for the diffusion from the reservoir through the channel to a field or an area (5) outside the microsensor.

25 8. Microsensor according to claim 6 or 7, characterized in that that a membrane or insert (4) open for diffusion of the tracer, is placed in sealing contact with the channel (2a), and that the tip (6) of the transducer or measuring device is placed in the membrane or insert.

30

9. Microsensor according to claim 6 characterized in that the tip (6) of the transducer (1) is placed in the mouth (3) of the passage- or transport area, and that the longitudinal axis of the transducer is parallel to  
35 the longitudinal axis (B) of the passage- or transport area.

10. Microsensor according to claim 6, characterized in that the tip (6) of the transducer (1) is placed in the mouth (3) of the passage- or transport area, and that the longitudinal axis of the transducer is mainly perpendicular to the axis (B, Fig.1) of the passage- or transport area.

11. Microsensor after any of the claims 6-10, characterized in that the mouth (3) of the reservoir has a size of between 2  $\mu\text{m}$  and 500  $\mu\text{m}$ , preferably 2  $\mu\text{m}$ .

12. Microsensor after any of the claims 6-11, characterized in that the reservoir contains at least one of following gasses: nitrous oxide ( $\text{N}_2\text{O}$ ), oxygen ( $\text{O}_2$ ), carbon monoxide ( $\text{CO}$ ) or hydrogen ( $\text{H}_2$ ), hydrogen ( $\text{H}_2$ ) being preferred, and that the membrane or insert (4) is gas permeable.

13. Microsensor according to any of the claims 6-11, characterized in that the reservoir contains a liquid with at least one non-ionized dissolved substance, and that the membrane or insert (4) is permeable for non-ionized substances.

14. Microsensor according to any of the claims 6-13, characterized in that the tip (6) of at least two transducers (1) are placed in the mouth (3) of the passage- or transport area.

15. Method for measuring diffusivity or flow velocity, the method comprising the use of a sensor with a mouth having at least one transducer characterized in that the sensor is placed in an area or a volumen of a medium, that a gas or a liquid dissolved material is diffused into the medium, that the diffusivity or flow velocity is determined by measuring a partial pressure gradient or a concentration gradient of the gas or the liquid

dissolved material, whereby the measurement is carried out in the mouth of the sensor by the transducer.

16. Microsensor for the measurement of diffusivity or  
5 flow velocity, the microsensor comprising a reservoir  
provided with a mouth and at least one transducer, characterized in that the transducer (1) has a tip (6),  
that the reservoir (2) surrounds the transducer (1),  
that the transducer tip is placed in the mouth (3), and  
10 that the reservoir (2) has a gas or a liquid dissolved  
substance determined for the diffusion from the reservoir (2) through the mouth (3) to a area or volumen (5)  
outside the mouth (3).

15

20

25

30

35

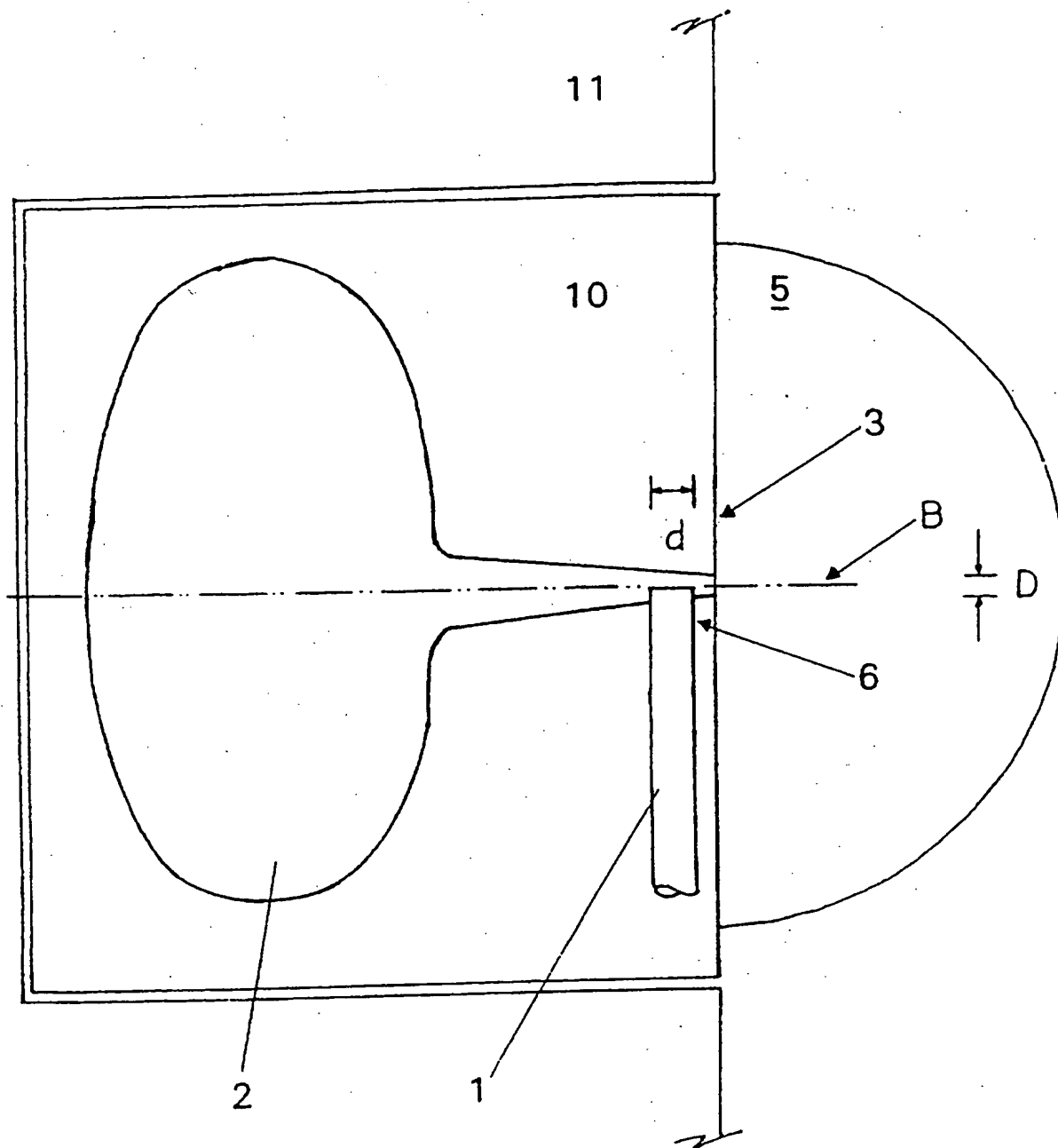


Fig. 1

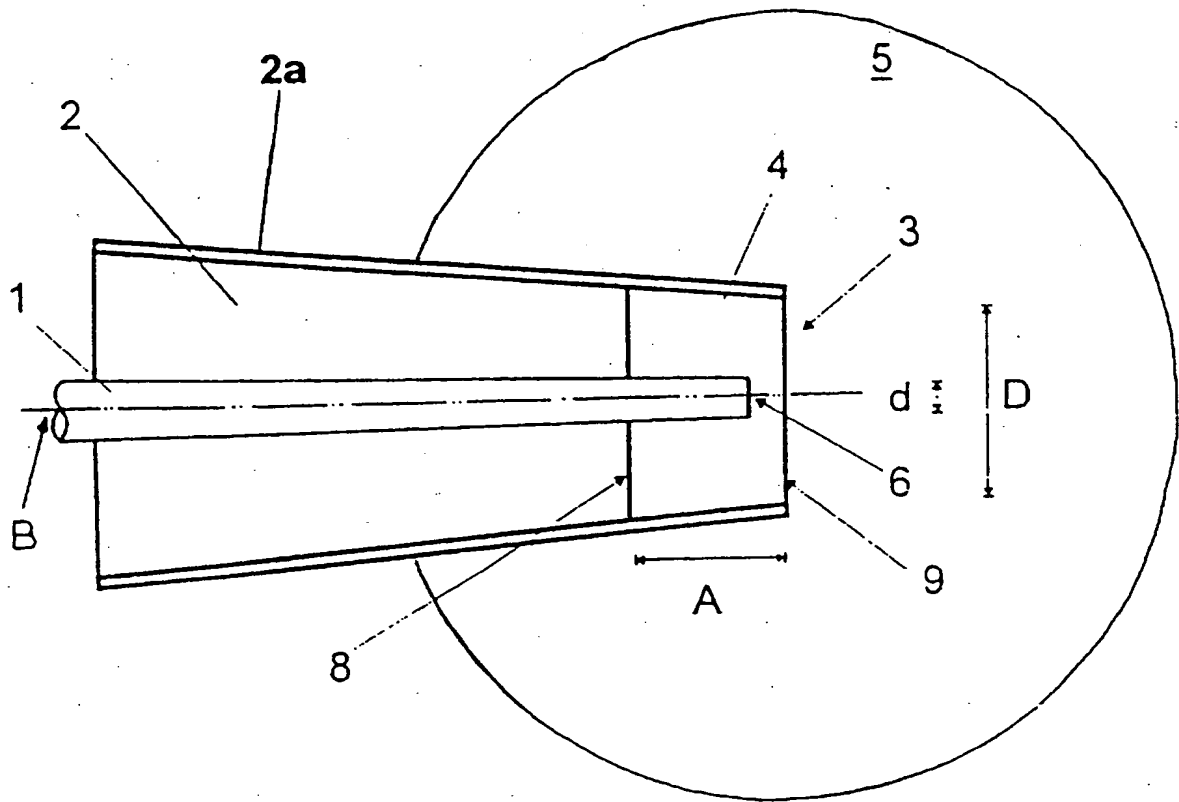


Fig. 2

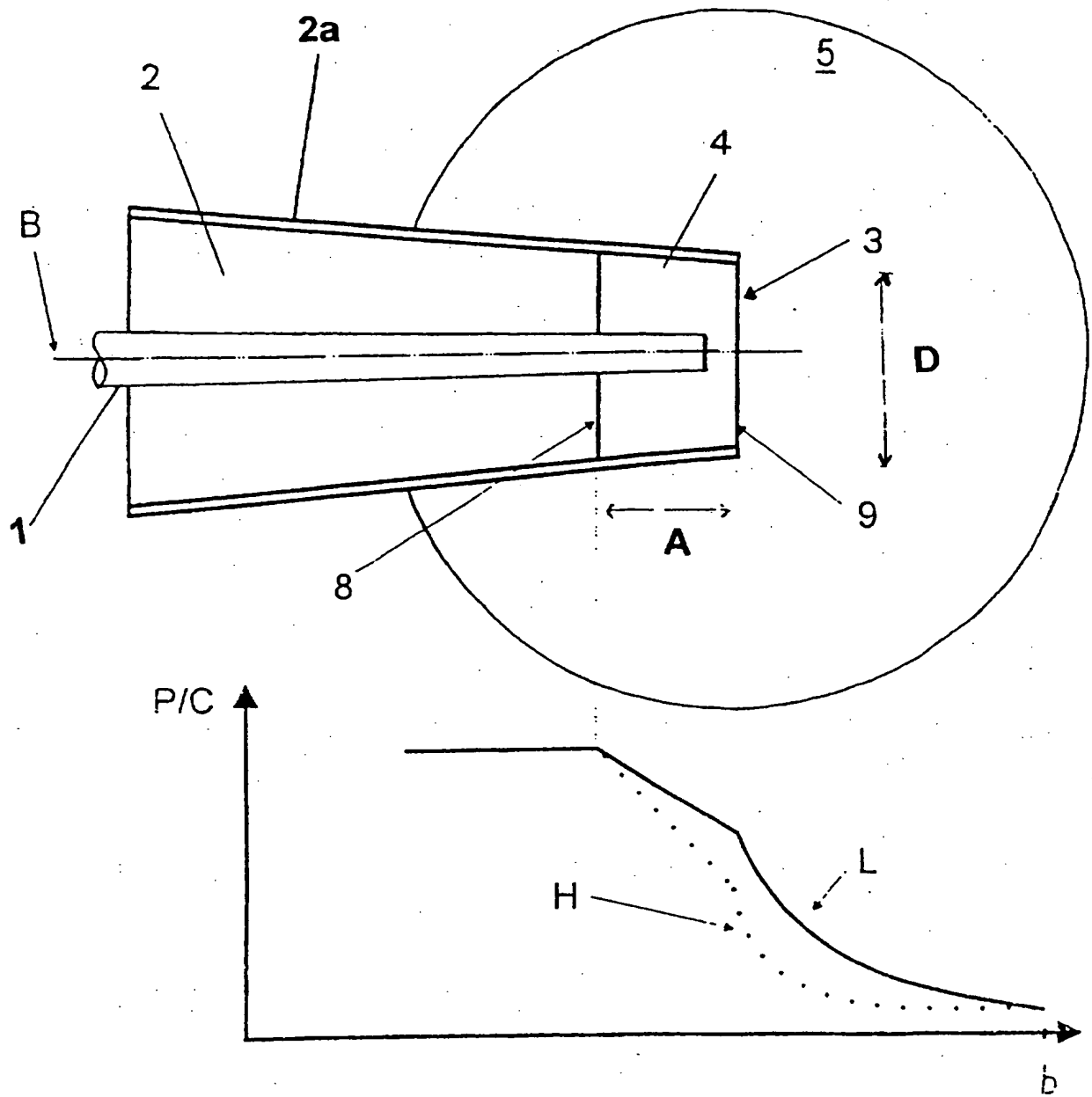


Fig. 3

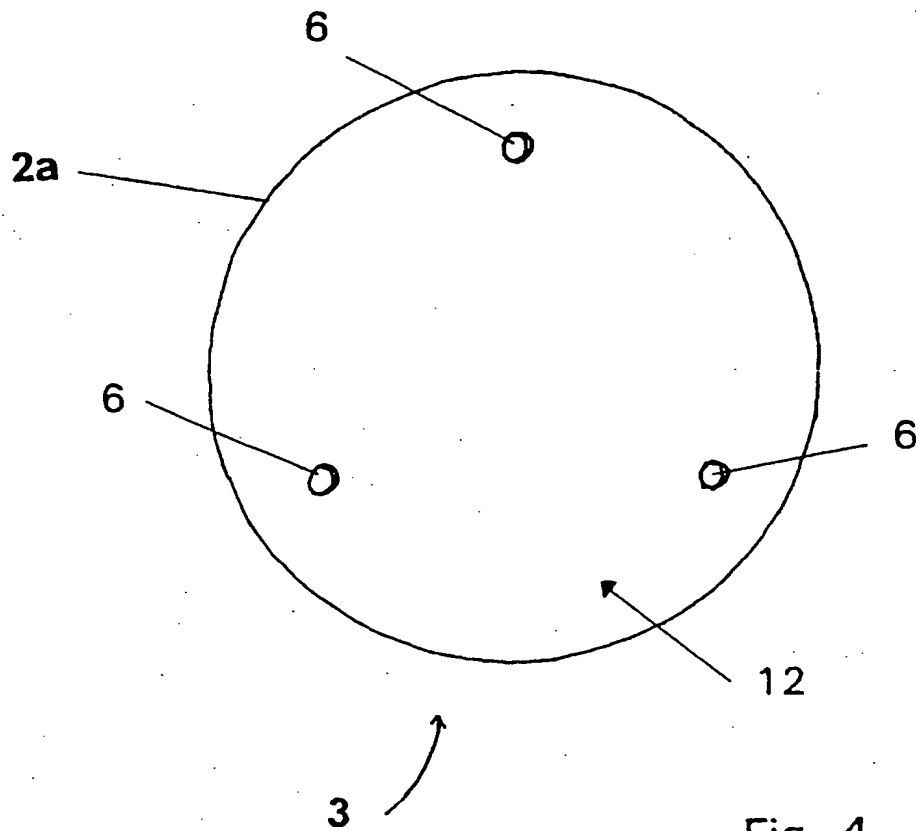


Fig. 4



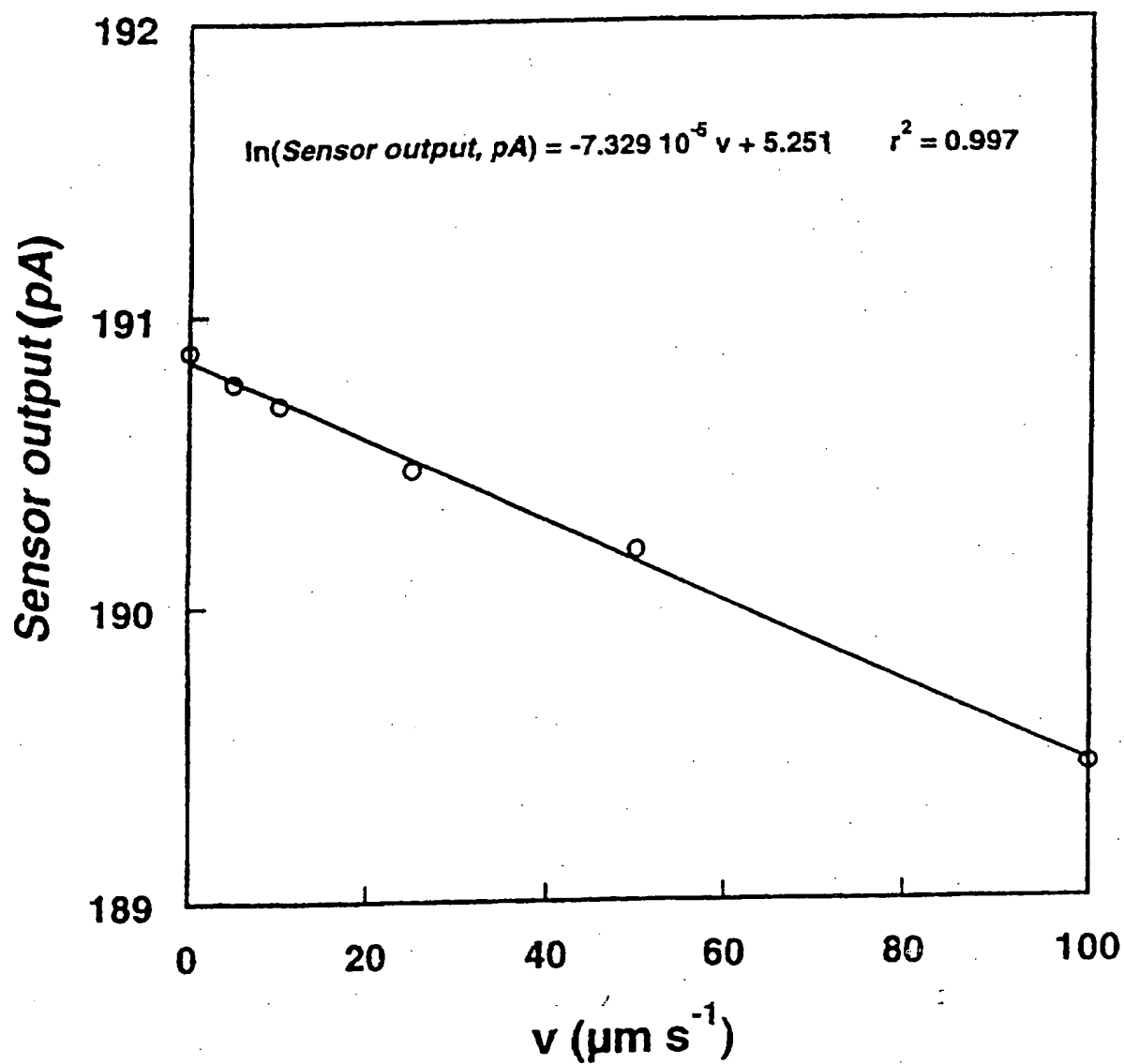


Fig. 5

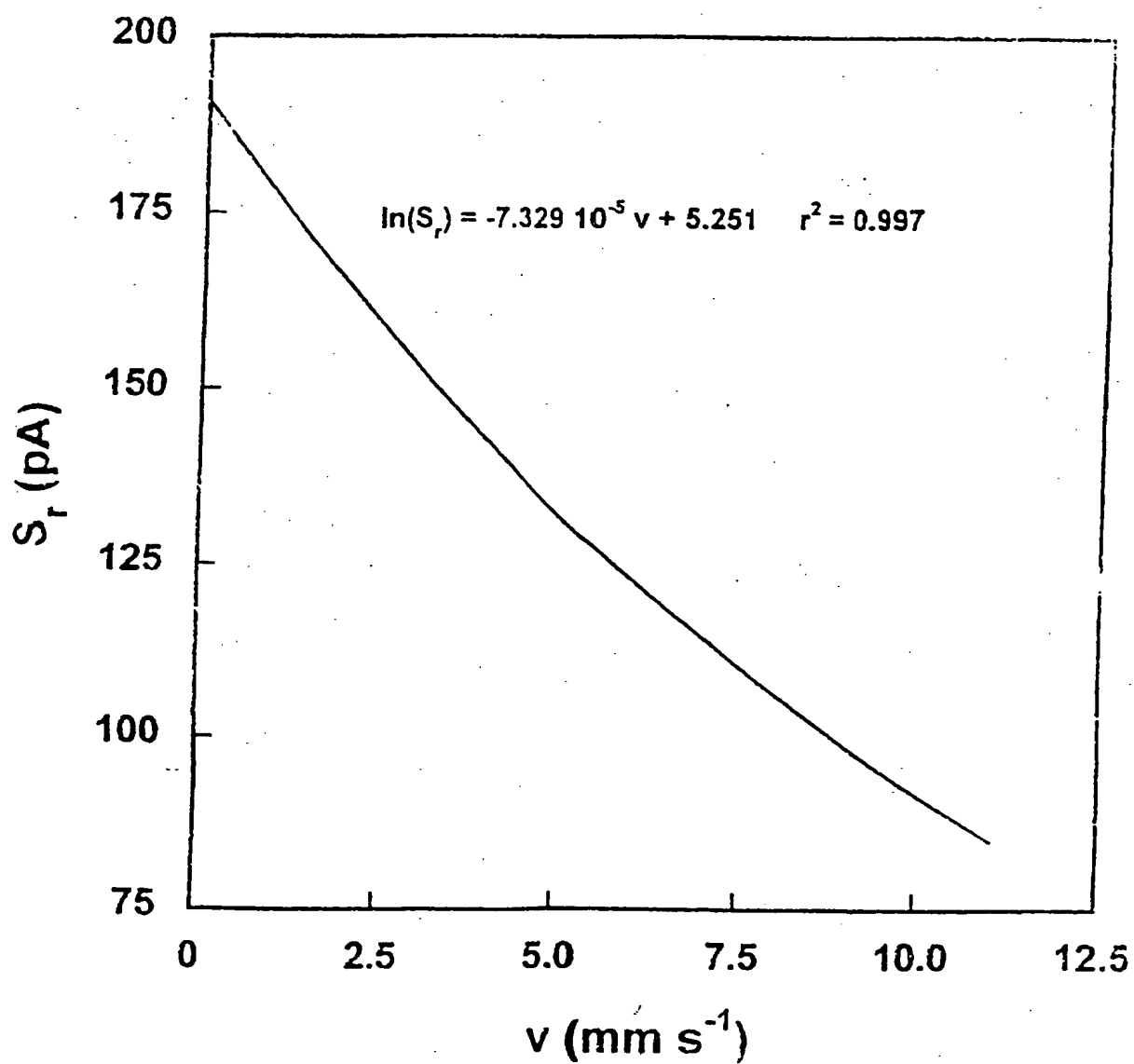


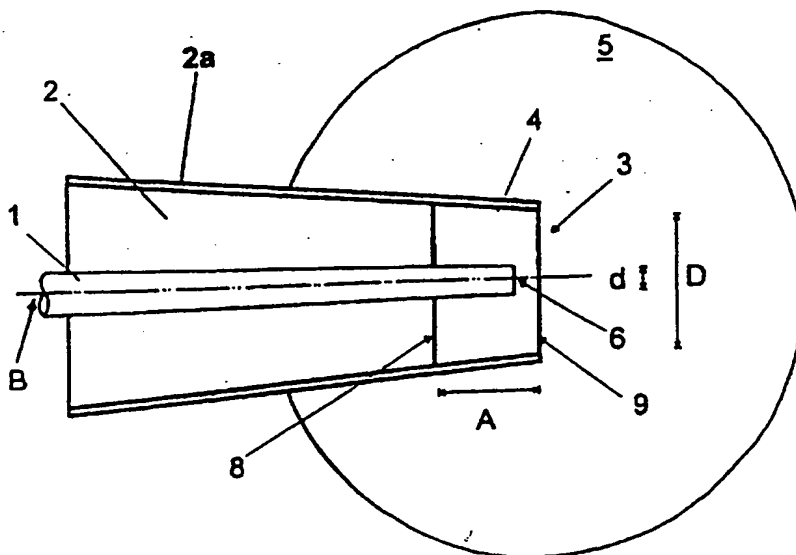
Fig. 6

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>G01F 1/64, 1/704</b>		<b>A3</b>	(11) International Publication Number: <b>WO 97/46853</b>
			(43) International Publication Date: 11 December 1997 (11.12.97)
(21) International Application Number: PCT/DK97/00250		(81) Designated States: AM, AT, AU, BA, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KR, KZ, LT, LU, LV, MD, MK, MX, NO, NZ, PL, PT, RO, RU, SE, SG, SI, SK, TR, UA, US, UZ, VN, YU, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).	
(22) International Filing Date: 4 June 1997 (04.06.97)			
(30) Priority Data: 0633/96 6 June 1996 (06.06.96) DK			
(71) Applicant (for all designated States except US): UNISENSE [DK/DK]; Forskerparken, Gustav Wieds Vej 10, DK-8000 Århus C (DK).		Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	
(72) Inventors; and (75) Inventors/Applicants (for US only): REVSBECH, Niels, Peter [DK/DK]; Thorshavnsgade 3, DK-8200 Århus N (DK). NIELSEN, Lars, Peter [DK/DK]; Mårslet Elle, Bedervej 83, DK-8320 Mårslet (DK). PEDERSEN, Ole [DK/DK]; Ørslevgade 76E, DK-4100 Ringsted (DK). GUNDERSEN, Jens, Kristian [DK/DK]; Søskrænten 19, DK-8260 Viby J. (DK).		(88) Date of publication of the international search report: 8 January 1998 (08.01.98)	
(74) Agent: DANFOSS A/S; Patent Dept., DK-6430 Nordborg (DK).			

(54) Title: METHOD FOR MEASUREMENT OF FLOW VELOCITY OR DIFFUSIVITY, MICROSENSOR AND APPLICATION OF SUCH MICROSENSOR

**(57) Abstract**

The invention relates to a method and a microsensor for measurement of transport coefficients like diffusivity or flow velocity. The microsensor has a reservoir (2) provided with a mouth (3) and a transducer (1). The transducer has a tip (6) placed in the mouth, which can be provided with a membrane or insert (4). The reservoir contains one or more gasses or one or more liquid-dissolved substances intended for the diffusion through the mouth into an area or field (5) of a medium outside the mouth of the reservoir. The transducer measures the partial pressure of the gas or the concentration of the liquid-dissolved substance in the mouth, whereby transport coefficients of diffusivity or flow velocity are determined. Preferably, the gradient of the partial pressure or the concentration is determined.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon	KR	Republic of Korea	PL	Poland		
CN	China	KZ	Kazakhstan	PT	Portugal		
CU	Cuba	LC	Saint Lucia	RO	Romania		
CZ	Czech Republic	LI	Liechtenstein	RU	Russian Federation		
DE	Germany	LK	Sri Lanka	SD	Sudan		
DK	Denmark	LR	Liberia	SE	Sweden		
EE	Estonia			SG	Singapore		

1  
INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 97/00250

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01F 1/64, G01F 1/704

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01F, G01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4501156 A (H.KRETSCHMER ET AL), 26 February 1985 (26.02.85), figure 1, abstract --	1,6,15,16
A	US 5207227 A (A.D.POWERS), 4 May 1993 (04.05.93), figures 1-9, abstract --	1,6,15,16
A	US 5339694 A (B.B.LOONEY ET AL), 23 August 1994 (23.08.94), figure 1, abstract -----	1,6,15,16

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "I" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
---	--

Date of the actual completion of the international search  19 November 1997	Date of mailing of the international search report  25.11.97
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer  Lars Jakobsson Telephone No. +46 8 782 25 00

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

01/10/97

International application No.

PCT/DK 97/00250

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4501156 A	26/02/85	AT 390143 B CS 245031 B DE 3212972 A,C FR 2509854 A,B GB 2103371 A,B JP 58024820 A SU 1702183 A	26/03/90 14/08/86 03/02/83 21/01/83 16/02/83 14/02/83 30/12/91
US 5207227 A	04/05/93	AU 7253591 A CA 2076667 A EP 0517734 A JP 5508328 T WO 9112765 A	18/09/91 03/09/91 16/12/92 25/11/93 05/09/91
US 5339694 A	23/08/94	NONE	